

Comment on *Towards a harmonized bionomenclature for life on Earth* (Hawksworth *et al.*, 1994)

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Introduction 'Whatever, and however little, we may think about such things, we are all of us bound to have some taxonomic concepts.' (Cain, 1959c, p. 302.)

The momentum towards a 'harmonized bionomenclature for life on Earth' seems sufficiently strong to suppose that it is broadly embraced by biologists (IUBS, 1994). The number and diversity of biological and nomenclatural organizations who participated in an exploratory meeting in 1994 (Hawksworth *et al.*, 1994, p. 213) documents the scope of the effort. Hawksworth *et al.* (1994) have summarized some points that are areas of concern in a 'harmonization' of bionomenclature. However, the direction, in our view, is leading toward nomenclatural procedures and 'protected' lists of names that will result in a systematic bipartisan nomenclature for life on Earth—and that seems to be contrary to harmonization.

Intention of a Harmonized Bionomenclature

We agree with the principle of a harmonized bionomenclature, and we believe that a set of panregional rules can be effectively implemented. This supposition is substantiated if the range of input from the roster of biologists and organizations represented at the 1994 exploratory meeting correctly reflects the range that would go into drafting a unified Code. The development of such a Code, including a much-needed glossary of biological nomenclature such as envisioned in the draft by Hawksworth (1994), would facilitate communication and decrease misunderstanding between systematists and other practising biologists.

Our concerns are about the role of standardized versus protected lists of organisms. There is bound to be some conflict between a unified Code and independent programs of nomenclatural standardization, because the existing, progressing programs have been brought into being without the benefit of a harmonized bionomenclature. Some lists may have to be revised to reflect the provisions of a unified Code. Some lists, wholly or in part, may become antique nomenclatural relics if a unified Code mandates lists of protected names.

The taproot of a unified Code of bionomenclature, as outlined by Hawksworth *et al.* (1994, p. 203), is the 'protection of Names in Current Use (NCUs)'. This could take the form of 'block conservation' (against specified other names) or of 'a new starting document which devalidates all unlisted names'; in the latter case names omitted from the list could 'be reinstated, then taking priority only from the date they are revived'. This passes far beyond the scope of such documents as the 'Official Lists and Indexes' of names issued by the ICZN, or the lists of conserved names that appear in the *International Code of Botanical Nomenclature* (Greuter *et al.*, 1994).

which reflect names conserved by plenary actions of international Commissions of nomenclature. Our assertion here is that the implementation of global lists of NCUs, as lists of 'protected names', may serve the intended purpose of stabilizing nomenclature for a greater set of practising biologists, but it is bound to destabilize work by the smaller, driving set of systematists. As we indicate below, there are many standard lists already in existence which fill the need for convenient reference by practising biologists and non-taxonomists. These standard lists have the great advantage that they can be periodically updated so as to reflect changes in systematic opinion; they are not rigid and 'infallible' lists of protected names.

Hawksworth *et al.* (1994, p. 192) indicated that a 1991 meeting of the International Union of Biological Sciences (IUBS) and the International Association for Plant Taxonomy (IAPT), on the stability of names (see Hawksworth, 1991), was convened because of the recognition 'that name changes for non-scientific reasons continue to inconvenience all users of the scientific names of organisms'. Hawksworth (1993) previously discussed the desirability of avoiding 'name changes for purely nomenclatural reasons'.

Hawksworth *et al.* (1994, pp. 189–191) have summarized the conclusions agreed by the 1994 exploratory meeting. Among them (item no. 4, p. 190) is the consideration 'that the availability of lists of published names, and the registration of new names in bacteriology, botany, virology and zoology, will make possible the harmonization of nomenclatural procedures in biology.' Indeed, Hawksworth (1992) has already elaborated upon 'the need for a more effective biological nomenclature for the 21st century'; there he called for the construction of lists of 'nomenclaturally protected names' and 'registration procedures' for new names.

The concept of registration is a broad one — it encompasses individual names as well as the publications in which they appear; it brings into reach the concept of 'protected' names and 'approved' publications. Although bacteriologists already subscribe to the principle of approved names, and the registration of new names only in the *International Journal of Systematic Bacteriology* (Skerman *et al.*, 1989; Hawksworth *et al.*, 1994, p. 204), outside this specialized discipline it should not be the function of an international Commission to either 'approve' or 'register' names or publications. A Commission can better serve biologists by establishing the means to formally collate names into nomenclators whose purpose is to document the existence (or availability) of the names; it should not drive systematics. Indeed, one of the primary missions of Systematics Agenda 2000 is 'to organize the information derived from this global program in an efficiently retrievable form that best meets the needs of science and society' (Systematics Agenda 2000, 1994, p. 1).

Hawksworth *et al.* (1994, p. 204) mention that for zoological names *Zoological Record*, published by Biosis International, 'is the proposed *de facto* registration office for new names'. We point out that Bouchet & Rocroi (1992, 1993) and Edwards & Thorne (1993) have discussed the significantly incomplete coverage of names of mollusks in *Zoological Record*. We are unaware of similar comparisons in other disciplines, but it would be worthwhile to make similar investigations for other zoological groups, and to first develop criteria to improve the recording of taxa.

A harmonized bionomenclature should be one that works for biologists; it should include the definitions of the purpose and components of taxonomic registers, and how they are to be updated; it should not identify 'approved' taxonomic registers. A

unified Code should create the means to more judiciously disseminate taxonomic names to biologists around the world.

'Standard' or 'Protected'? Bionomenclature or Bi-Nomenclature?

Nomenclators striving for comprehensiveness have been published since the mid-19th century. Modern ones exist for many aspects of zoology and botany, for which citations are nearly superfluous. These include such principal sources as *Zoological Record*, issued yearly since 1864 in parts organized by major taxonomic groups (with a gap 1907–1914 that was filled by the *International Catalogue of Scientific Literature*, [Part] N. Zoology); *Index Animalium* (Sherborn, 1902–1933); *Nomenclator Zoologicus* (Neave *et al.*, 1939–1993); *Index Kewensis*, the nomenclator for flowering and seed-bearing plants, begun with Jackson (1894–1895), followed by 21 supplements to date; and the *Index Nominum Genericorum (Plantarum)* (Farr *et al.* 1979, 1986). A CD-ROM amalgamation of Neave's *Nomenclator* and *Zoological Record* has been proposed for generic names. Specialized nomenclators for major organismic groups also exist; for example, the *Catalogue of the Fossil and Recent Genera and Species of Diatoms and their Synonyms* (VanLandingham, 1967–1979), the *Treatise on Invertebrate Paleontology* (Moore *et al.*, 1953–1992), or *Fossilium Catalogus*, published in two series, 'I: Animalia', since 1913 thus far in 134 parts, and 'II: Plantae', since 1913 thus far in 95 parts). All of these, while indispensable, are principally reference works; they record taxonomic nomenclature usually at the level of genera and species. Some, such as Sherborn and Neave, do not deal with synonymization; others, such as VanLandingham, do list taxa according to senior and junior synonyms.

Beyond the nomenclator is the 'standard list', for which a formal definition is lacking (cf. Hawksworth, 1994). Generally, a standard list is an itemization of taxa known to occur in a region (for geographic lists) or in a systematic group (for systematically organized lists). There is already significant momentum toward nomenclatural standardization through the publication of standard lists. This is being accomplished within different systematic groups as well as for separate geographical areas. Such lists have been prepared by individual researchers, and by consortia and committees of professional biologists working at the behest of organizations and governmental agencies. The organization and function of each list reflects the intended use of the list; some are taxonomic and nomenclatural guides (e.g., *Dermapterorum Catalogus* (Sakai, 1970–1995), *Catalog of the Genera of Recent Fishes* (Eschmeyer, 1990)), some reflect international concerns that provide guidance for national and internal programs of regulation and conservation (such as lists of endangered and threatened organisms; e.g., Groombridge, 1993), and others are more bureaucratic in scope (such as candidate review lists of endangered or threatened species; e.g., U.S. Fish and Wildlife Service, 1994). Standard lists are inherently biased; they are compromised by arbitrarily selecting one named taxon to represent what, in the opinion of some systematists, might be identified as another or several taxa. Some lists are simple listings of names, sometimes accompanied by directories of common names (e.g. Hart, 1994), while others are themselves contributions to systematics.

We can cite examples largely from among the rapidly accumulating standard lists of organisms in North America, but lists for other regions of the world, and for the

whole world, are also becoming available. For instance, the American Fisheries Society produces a series of lists that are on a cycle of revisions appearing every ten years. They itemize recently named new species and necessary nomenclatural changes; changes are explained and justified in the texts. Currently there are checklists for fishes (Robins *et al.*, 1991), mollusks (Turgeon *et al.*, 1988; second edition in review), decapods (Williams *et al.*, 1989), and ctenophorans and cnidarians (Cairns *et al.*, 1991). Among works in review or in preparation are the volumes on crustaceans, annelids, aquatic insects, echinoderms, sponges, bryozoans, and 'miscellaneous' groups.

The Check-List of European Marine Mollusks (CLEMAM) is a current project for the development of a checklist of the marine mollusks of Europe, and many European countries are developing maps and lists of land and freshwater mollusks. Insect groups, particularly those of agricultural concern, have been the subject of extensive lists from early in the 20th century. Standard lists exist for the Orthoptera of the world (Otte, 1994a-c), birds of the world (Sibley & Monroe, 1990) and mammals of the world (Nowak, 1991; Wilson & Reeder, 1993). The Food and Agriculture Organization (FAO) of the United Nations produces an extensive series of annotated world catalogues of 'Species of Interest to Fisheries'. Lists are now playing an important part in endangered-species programs such as those under the U.S. Fish and Wildlife Service, the International Union for the Conservation of Nature (IUCN), and aspects of the Convention on International Trade in Endangered Species (CITES) that regulates importation and exportation of some biological materials. Regional floras are equally ambitious in their presentation, ranging from simple taxonomic lists to systematic revisions.

Systematic monographs that are themselves standard lists include, for example, the *Land Mollusca of North America (North of Mexico)* (Pilsbry, 1939-1948), and *The Diatoms of the United States* (Patrick & Reimer, 1966, 1975). Problems are met when attention is turned away from taxonomic groups that either have economic importance (as with agriculture) or are well-studied in developed parts of the world. Also, the paucity of systematic investigators in some groups of organisms ensures that there are many antiquated taxonomic lists that have little hope of being updated soon, and we question how 'protected' lists will affect the taxonomy of these groups. Additional concerns are seen by some researchers who disagree with the identity of taxa that appear in the standard lists. This disparity results from redirected focuses of biological education and from a skewed distribution of researchers both geographically and taxonomically.

Systematics Agenda 2000, a consortium of taxonomic and systematic societies working in cooperation with the Association of Systematics Collections, has developed a long-range plan for describing the remaining undescribed species in the world in the next 25 years (Systematics Agenda 2000, 1994). The plan is divided into three missions: to inventory, to describe diversity and develop a predictive classification of life on Earth, and to put all of this information into an efficiently organized database. Some ideas for a global database have been enacted by Species 2000, a World Species Enumeration program adopted in 1994 by the IUBS. The kinds of databases envisioned by these projects have the potential to serve as the basis for a global nomenclator of names.

We agree that the compilation of regional or global lists of taxa should be conducted by specialist societies for the region or taxonomic group concerned. Regional lists thus can be incorporated into a global list by the international society representing the taxonomic group; for example, *Unitas Malacologica* could oversee the development and production of a global list of mollusks. But all lists must be developed by those systematists working on the groups, to be complete and effective. The role of the major systematic societies is to facilitate the interaction of the specialists and to provide the incentive for development of these lists. The role of an international Commission of nomenclature should be to coordinate the progress of the systematic societies and smaller groups who are working with organisms for which there are no international societies. Extending further the utility of databases, we cite the example of the North American Diatom Ecological Database (NADED; Charles & Acker, 1994), which applies itself to both modern and paleoecological investigations; it is founded upon a standard list of diatoms but, being in a database format, it can be correlated to other taxonomic listing schemes.

The concentration of biological work today is less upon systematics and taxonomy and more upon applied work which demands specific taxonomic criteria by which to report its findings. Thus it is usually in environmental studies that the 'inconveniences' of taxonomic citations in 'non-scientific' contexts arise. Once a standard list is available for taxonomic groups or regional censuses, systematists and other research biologists who have need to pay attention to the details of taxonomy will develop their own 'working lists', probably with synonymies pointing to the standard or protected lists. The purpose of many of the existing standard lists of organisms is to be a 'working list'.

Central to the problem of 'non-scientific' uses of scientific names is nomenclatural change resulting from the application of the principles of priority and homonymy; for names to have fuller meaning and unique identities the author and date are appended. The 1994 meeting recommended (Hawksworth *et al.*, 1994, p. 190) 'that, considering divergent rules and traditions concerning author citations for scientific names, use of such citations be made optional (and be recommended only in a strictly taxonomic context) ...'. The importance of author and date to the principle of priority, and to the effective treatment of homonyms especially in botany, was recognized (pp. 201–202). It was suggested (p. 202) that 'protected lists of some kind' could effectively deal with problems in the future. This we believe can contribute to a dichotomous Code, in part controlling lists for 'non-scientific' uses, and in part controlling special applications of formal taxonomic nomenclature for 'scientific uses'. Hawksworth *et al.* (1994) intimated, too, that citations may be omitted for 'familiar' taxa, as is the practice in bacteriology and zoology. What is to determine the limits to 'familiarity'? The practice extends even to the binomen itself, as with the case of the *E. coli* bacterium, and further, to non-binomial familiarity as with the monospecific fossil avian genus *Archaeopteryx*. Such scientific names essentially have attained the status of common names, much as with alligator or gorilla.

The use of the author and date of the original publication of a scientific name is absolutely imperative to locate the original publication in which (in the case of zoology) the nominal taxon was proposed or in which (in the case of botany) the

epithet was created. Yu (1993), recognizing the problem in zoological nomenclature, proposed a system to deal with the original and subsequent combinations of a species-group name. Spamer & Bogan (1994) pointed out that the problem was a limitation of technology, not one of nomenclature, and that there are ways to deal with the perceived problem with author and date without making the system unwieldy. The proposed elimination of complete scientific names in non-taxonomic works is an attempt to bypass the same problem which caused Yu to construct a polynomial nomenclature — except that in Yu's system the identity of the original name was not lost.

Without the correct association of author and date, any database or list is useless. A standard list would, of course, include the author and date of a name; but establishing it as a 'protected list', without provisions for periodic updates, creates a punctuated equilibrium for the taxonomy of the group so listed. It encourages the creation of nomenclaturally invalid 'working lists', which would be updated only as frequently as there is a perceived need (or possibly even as infrequently as funding will allow). Taxonomic groups that have few practicing systematists will, as they do now, suffer for the lack of an adequately modern key. The end result is a bi-nomenclature consisting of sanctioned lists and systematically updated 'working' lists. The implementation of protected lists mandated by a unified Code of bionomenclature is bound to formalize a bipartisan kind of scholarship—one for common use or quick reference by non-scientists and reconnaissance biologists, the other for the more specialized work of systematics. It is possible that works in systematics will have to adopt the protected lists in order to declare themselves valid for the purposes of taxonomic nomenclature, a confining and arbitrary regulation in an aspect of science which admits itself even now to study sets of artificially derived 'relationships' between organismic groups.

A unified Code of nomenclature will have to consider that a bi-nomenclature can exist for any given taxonomic group. The Code will have to formally address the bipartisan use of scientific names, one in an 'non-scientific' context, the other in a 'scientific' context. The protected list of names will be one kind of nomenclator; it will include arbitrated authors and dates for taxa, possibly resulting in citations that are contrary to the principles that are in use now but with which there are many perceived problems. Another kind of nomenclator will be the systematically precise list that may follow the traditional principles of rules and Codes that have been developed mainly in the 20th century; these are bound to appear in the literature despite the provisions of a unified Code. In the middle fall specialized indices that will in some way have to be correlated with the standard lists; for example, the *Index to Plant Chromosome Numbers* (latest instalment by Goldblatt & Johnson, 1994). To moderate the different rules, a unified Code will have to clearly indicate the derivation of its Articles, and the purposes for which they deviate from the Articles of existing Codes. A correlation between the Articles of previous Codes and a unified Code will be indispensable — it should be mandatory (see for an example Greuter *et al.*, 1994, pp. xvi–xvii).

Irrespective of the extent to which scientific names are pruned, and to what length the procedures of taxonomic nomenclature are made less formal in non-taxonomic contexts, standard lists will have much less utility if information about them is not disseminated to biologists worldwide. So long as broad changes may be in the offing

for taxonomic nomenclature, international Commissions of nomenclature should at least establish the means to document standard lists and aggressively make the information widely available.

Lists, Surveys, Systematics, and Education

Biological surveys have placed great demands upon systematic and nomenclatural resources. Working often against deadlines, biologists are increasingly having to resort to quick, incomplete, or adopted identifications of organisms. Placed usually in an environmental context, these surveys are often having to determine, without much time to question, the taxonomic identities of a panregional set of organisms. Depending upon the context or objective of the survey, or the taxonomic abilities of the investigators, identifications may mix levels of precision in a single report: species, genus, or suprafamilial group, sometimes even to undivided class; at the extreme end, too, is often a category for 'Other' organisms.

Aside from the constraints of time, money and skill, there are many reasons for the variety of taxonomic laxness that is perceived in some surveys. The end product is usually directed to administrative purposes; the end users themselves are most often not scientists. To the lay reader, a species is a species, without much ambiguity; the finer points of morphological variation, even hybridization, are extraneous; the concepts of taxonomic nomenclature are superfluous. The abstracted approach to taxonomy, directed by pragmatic constraints of bureaucracy and fiscal accountability, has contributed to the decline of systematics and 'alpha taxonomy' in education. Practical training is more in 'biodiversity' and applied ecology. Schools today are turning out a new community of environmental and biological investigators, students who have had only very focused training in some aspects of taxonomy and systematics. It is this same group of people who are charged with establishing the identity (and thus also the systematic placement) of the estimated '12 to 118 million' species living on Earth that have not been scientifically described (Groombridge, 1992).

To accomplish the goal of rapid biological reconnaissances, workers are looking toward very streamlined introductions to taxonomic identification. The only way to make this possible is through easily usable keys and standard lists; it leaves little room for reinterpretation, which is beyond the scope of the environmental survey and left to systematic studies. 'Training' of non-specialist workers will be pitifully brief, in some cases less than a day (Beattie & Oliver, 1994), and thereafter great reliance is placed on the key and list. These are the very people who will be the significant contributors of taxonomic identifications in biodiversity databases and indices, which in turn will be the legislative tools for environmental monitoring and regulation. Ravera (1995, p. 2) has pointed out that biodiversity data based on less expensively and more quickly assembled data are preferred over 'more scientific methods', and that the literature on the application of diversity indices to specific ecological problems is far smaller than the literature on quantitative determinations of diversity. The trend is clearly toward non-specialists, directed only peripherally by trained workers, deriving data that must seem to unambiguously guide non-scientists in their efforts to moderate environmental and social problems. The methods will not be encumbered by non-essential academic aspects, such as a precisely regulated taxonomic nomenclature.

Central to the work of the next generations of biologists will be the computerized database. Making the information in it widely available and reliably updated are major tasks that have gone neither unnoticed nor without consideration of the manifold applications to biological research and social projects (Systematics Agenda 2000, 1994). These databases are founded upon the data in biological collections (Hawksworth & Mound, 1991), which in turn are the sets of voucher specimens upon which standard lists are compiled. We ask whether then there is the need to establish 'standard collections'? We question how the identifications of organisms in other collections will be adequately correlated with the names that appear in standard lists, for if an identification in the collection does not correspond to one in the list of 'approved' names, will ambiguity thus be introduced to 'non-scientific' work?

We challenge the developers of a unified Code of nomenclature to devise the means by which systematics, so crucial toward understanding what we mean by 'life on Earth', is not sterilized further by making it more difficult to understand how the previous three centuries of biologists defined 'life on Earth' (for concepts, see for example Cain, 1956–1962; Cole, 1984; Hawksworth & Bisby, 1988; Starobogatov, 1991). If we are to recreate taxonomy for 'non-scientific' purposes, should we perhaps turn toward the numerical lists of taxa which have been attempted in the past (Heppell, 1991)?

Conclusion

Biologists speak of nomenclature 'in the 21st century'; it is nigh. Checklists of organisms will be the guides for the next generations of biologists. Accordingly, we are to presume that if an organism cannot be assigned to a name that appears on one of the standard or approved lists, it could be construed as being new to science. The rigorous aspects of author, date, and priority for all taxonomic work back to the time of Linnaeus are, in part anyway, thus relegated to the oversight of historians of science. We purposely avoid here an emotional debate that could ensue, about the wisdom of such an approach to biology, but we will admit that biological research as we know it has changed already; it is not something that will happen 'in the next century'. The rules do now need to catch up. It is important to consider that a panregional series of standard, updatable lists of scientific names can do much to stabilize current nomenclature, and that lists of protected names ('NCUs') can introduce confusion into the methods of subsequent recognition of species and higher taxa. There will be workers who need to study the broad literature of systematic biology prior to the implementation of a unified Code. It will be a task of Herculean proportions to correlate the names in the 'antique' literature of the first three centuries of modern biological work with the names conserved by a 'starting list' of Earth's organisms.

Work toward a unified Code of nomenclature will have to very carefully measure the impact of its provisions on the satisfactory identification of organisms; the grand census of life of Earth that we strive toward will depend upon it. The Code also will have to consider the negative effects that an officially sanctioned list of publications can have upon work carried out in less-developed regions of the world, where biologists work under extraordinary conditions that jeopardize the timely and successful dissemination of their work. We must not make it appear that the results of biological work conducted in a technologically and bibliographically richer

environment is more worthy of coordination and dissemination than is the work conducted outside these more fortunate environments.

It is a far greater imperative to disseminate the information of taxonomy than to simply establish sets of rules that will apply differently to different work contexts. A unified Code of bionomenclature, rather than establishing a protected list of taxa, should provide the procedures for the composition and updating of taxonomic registers—standard lists. It would do well to establish the means by which the authors of taxonomic works are responsible for centrally recording the taxonomic acts they make in publications. The Code should provide the criteria by which taxonomic data are then effectively disseminated to the scientific community. 'Availability' means nothing to the researcher who is not informed.

References

- Beattie, A.J. & Oliver, I. 1994. Taxonomic minimalism. *Trends in Ecology and Evolution (TREE)*, **9**: 488–490.
- Bouchet, P. & Rocroi, J.-P. 1992. Supraspecific names for molluscs: a quantitative review. *Malacologia*, **34**: 75–86.
- Bouchet, P. & Rocroi, J.-P. 1993. The lottery of bibliographical databases: a reply to Edwards & Thorne. *Malacologia*, **35**: 407–410.
- Cain, A.J. 1956. The genus in evolutionary taxonomy. *Systematic Zoology*, **5**: 97–109.
- Cain, A.J. 1959a. Deductive and inductive methods in post-Linnean taxonomy. *Proceedings of the Linnean Society of London*, **170**: 185–217.
- Cain, A.J. 1959b. The post-Linnean development of taxonomy. *Proceedings of the Linnean Society of London*, **170**: 234–244.
- Cain, A.J. 1959c. Taxonomic concepts. *Ibis*, **101**: 302–318.
- Cain, A.J. 1962. The evolution of taxonomic principles. *Symposia of the Society for General Microbiology*, no. 12 (Microbial Classification): 1–13.
- Cairns, S.D., Calder, D.R., Brinckmann-Voss, A., Castro, C.B., Pugh, P.R., Cutress, C.E., Jaap, W.C., Fautin, D.G., Larson, R. J., Harbison, G.R., Arai, M.N. & Opresko, D.M. 1991. Common and scientific names of aquatic invertebrates from the United States and Canada: Cnidaria and Ctenophora. *American Fisheries Society Special Publications*, **22**: 1–75.
- Charles, D.F. & Acker, F.W. 1994. *Design for a North American Diatom Ecological Database (NADED)*. Poster presented at the 13th International Diatom Symposium, 1–7 September 1994, Acquafredda di Maratea (PZ), Italy.
- Cole, C.J. 1984. Taxonomy: what's in a name? *Natural History*, **93**(9): 30, 32–34.
- Edwards, M.A. & Thorne, M.J. 1993. Reply to 'Supraspecific names of molluscs: a quantitative review'. *Malacologia*, **35**: 153–154.
- Eschmeyer, W.N. 1990. *Catalog of the genera of Recent fishes*. 697 pp. California Academy of Sciences, San Francisco.
- Farr, E.R., Leussink, J.A. & Stafleu, F.A. (Eds.). 1979. *Index nominum genericorum (plantarum)*, 3 vols. (Regnum vegetabile, vols. 100–102). Bohn, Scheltema & Holkema, Utrecht, and W. Junk, The Hague.
- Farr, E.R., Leussink, J.A. & Zijlstra, G. (Eds.). 1986. *Index nominum genericorum (plantarum)*. Supplementum I, (Regnum vegetabile, vol. 113). 126 pp. Bohn, Scheltema & Holkema, Utrecht and Antwerpen, and W. Junk, The Hague and Boston.
- Goldblatt, P. & Johnson, D.E. 1994. Index to plant chromosome numbers; 1990–1991. *Monographs in Systematic Botany from the Missouri Botanical Garden*, **51**: 1–267.
- Greuter, W., Barrie, F.R., Burdet, H.M., Chaloner, W.G., Demoulin, V., Hawksworth, D.L., Jorgensen, P.M., Nicolson, D.H., Silva, P.C., Treharne, P. & McNeill, J. (Eds.). 1994. *International code of botanical nomenclature* (Tokyo Code). (Regnum vegetabile, vol. 131). 389 pp. Koeltz Scientific Books, Königstein.

- Groombridge, B. (Ed.). 1992. *Global biodiversity: status of the Earth's living resources*. World Conservation Monitoring Centre, Chapman & Hall, London.
- Groombridge, B. (Ed.). 1993. *1994 IUCN Red List of threatened animals*. lvi, 286 pp. IUCN, Gland, Switzerland, and Cambridge, U.K.
- Hart, C.W., Jr. 1994. A dictionary of non-scientific names of freshwater crayfishes (Astacoidea and Parastacoidea), including other words and phrases incorporating crayfish names. *Smithsonian Contributions to Anthropology*, **38**: 1–127.
- Hawsworth, D.L. (Ed.) 1991. *Improving the stability of names: needs and options; proceedings of an international symposium*. Kew, 20–23 February 1991 (Regnum vegetabile, vol. 123). 358 pp. Koeltz Scientific Books, Königstein.
- Hawsworth, D.L. 1992. The need for a more effective biological nomenclature for the 21st century. *Botanical Journal of the Linnean Society*, **109**: 543–567.
- Hawsworth, D.L. 1993. Name changes for purely nomenclatural reasons are now avoidable. *Systema Ascomycetum*, **12**: 1–6.
- Hawsworth, D.L. (Ed.). 1994. A draft glossary of terms used in bionomenclature. *IUBS Monograph*, **9**: 1–74.
- Hawsworth, D.L. & Bisby, F.A. 1988. Systematics: the keystone of biology. Pp. 3–30 in Hawsworth, D.L. (Ed.), *Prospects in systematics*. Clarendon Press, Oxford, for the Systematics Association.
- Hawsworth, D.L., McNeill, J., Sneath, P.H.A., Treharne, R.P. & Tubbs, P.K. (Eds.). 1994. Towards a harmonized bionomenclature for life on Earth. *Bulletin of Zoological Nomenclature*, **51**: 188–216. [Also published as *Biology International*, Special Issue no. 30.]
- Hawsworth, D.L. & Mound, L.A. 1991. Biodiversity databases: the crucial significance of collections. Pp. 17–29 in Hawsworth, D.L. (Ed.), *The biodiversity of microorganisms and invertebrates: its role in sustainable agriculture*. CAB International.
- Heppe, D. 1991. Names without number? Pp. 191–196 in Hawsworth, D.L. (Ed.), *Improving the stability of names: needs and options*. (Regnum vegetabile vol. 123). Koeltz Scientific Books, Königstein.
- IUBS (International Union of Biological Sciences). 1994. *IUBS Reports of the 25th General Assembly, 5–9 September, 1994, Paris, France*, 11 pp. Paris.
- Jackson, B.D. 1894–1895. *Index Kewensis*, 4 vols. Clarendon Press, Oxford.
- Moore, R.C. et al. (Eds.). 1953–1992. *Treatise on invertebrate paleontology*, in 21 parts. Geological Society of America, and University of Kansas Press, New York, Boulder, and Lawrence.
- Neave, S.A. et al. (Eds.). 1939–1993. *Nomenclator zoologicus*, 8 vols. Zoological Society of London, London.
- Nowak, R.M. 1991. *Walker's mammals of the world*. 1,732 pp. Johns Hopkins University Press.
- Otte, D. 1994a. *Orthoptera species files. 1. Crickets (Grylloidea); a systematic catalogue*. 120 pp. The Orthopterists' Society and the Academy of Natural Sciences of Philadelphia, Philadelphia.
- Otte, D. 1994b. *Orthoptera species file. 2. Grasshoppers [Acridomorpha]. A. Eumastacoidea, Trigonopterygoidea, Pneumoroidea*. 162 pp. The Orthopterists' Society and the Academy of Natural Sciences of Philadelphia, Philadelphia.
- Otte, D. 1994c. *Orthoptera species file. 3. Grasshoppers [Acridomorpha]. B. Pamphagoidea*. 241 pp. The Orthopterists' Society and the Academy of Natural Sciences of Philadelphia, Philadelphia.
- Patrick, R. & Reimer, C.W. 1966. The diatoms of the United States; exclusive of Alaska and Hawaii. Volume 1. Fragilariaceae, Eunotiaceae, Achnantheae, Naviculaceae. *Monographs of the Academy of Natural Sciences of Philadelphia*, **13** [Vol. 1]: 1–688.
- Patrick, R. & Reimer, C.W. 1975. The diatoms of the United States; exclusive of Alaska and Hawaii. Volume 2, Part 1. Entomoneidaceae, Cymbellaceae, Gomphonemaceae, Epithemiaceae. *Monographs of the Academy of Natural Sciences of Philadelphia*, **13** [Vol. 2, Pt. 1]. 213 pp.
- Pilsbry, H.A. 1939–1948. Land Mollusca of North America (North of Mexico). *Monographs of the Academy of Natural Sciences of Philadelphia*, **3**. Vol. 1, Part 1, pp. 1–573 (1939);

- Vol. I, Part 2, pp. 575–994 (1940); Vol. II, Part 1, pp. 1–520 (1946); Vol. II, Part 2, pp. 521–1113 (1948).
- Ravera, O. 1995. Working group on biological monitoring. *SILNEWS (International Association of Theoretical and Applied Limnology)*, 15: 1–2.
- Robins, C.R., Bailey, R.M., Bond, C.E., Brooker, J.R., Lachner, E.A., Lea, R.N. & Scott, W.B. 1991. Common and scientific names of fishes from the United States and Canada. Ed. 5. *American Fisheries Society Special Publications*, 20: 1–183.
- Sakai, S. 1970–1995. *Dermapterorum catalogus; a basic survey for integrated taxonomy of the Dermaptera of the world* [title varies, thus far in 30 parts]. Department of Biology and Chemistry, Daito Bunka University [and Ikegami Book Publishing Co., c/o Daito Bunka University], Sendagi, Bunkyo, Tokyo.
- Sherborn, C.D. 1902–1933. *Index animalium*, 10 vols. British Museum, London.
- Sibley, C.G. & Monroe, B.L., Jr. 1990. *Distribution and taxonomy of birds of the world*. 1111 pp. Yale University Press, New Haven.
- Skerman, V.D.B., McGowan, V. & Sneath, P.H.A. 1989. *Approved lists of bacterial names*. Amended edition. American Society for Microbiology, Washington, D.C.
- Spamer, E.E. & Bogan, A.E. 1994. Towards a polynomial system of zoological nomenclature? A response to the proposals of D.S. Yu (1993). *Bulletin of Zoological Nomenclature*, 51: 92–97.
- Starobogatov, Ya.I. 1984. O problemakh nomenklatury vysshikh taksonomicheskikh kategoriy. Pp. 174–187 in Tatarinov, L.P. & Shimanskiy, V.N. (Eds.), *Spravochnik po sistematike iskopayemykh organizmov (taksony otryadnoy i vysshikh grupp)*. [Handbook on the systematics of fossil organisms (taxa of ordinal and higher groups)]. Izdatel'svo Nauka, Moscow. [A translation is Starobogatov (1991).]
- Starobogatov, Ya.I. (translated by Grygier, M.J.). 1991. Problems in the nomenclature of higher taxonomic categories. *Bulletin of Zoological Nomenclature*, 48: 6–18. [First appeared in Russian in 1984.]
- Systematics Agenda 2000. 1994. *Systematics Agenda 2000: charting the biosphere*. Technical report. 34 pp. Systematics Agenda 2000, a consortium of the American Society of Plant Taxonomists, the Society of Systematic Biologists, and the Willi Hennig Society, in cooperation with the Association of Systematics Collections. New York and Washington.
- Turgeon, D.D., Bogan, A.E., Coan, E.V., Emerson, W.K., Lyons, G., Pratt, W.L., Roper, C.F.E., Scheltema, A., Thompson, F.C. & Williams, J.D. 1988. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks. *American Fisheries Society Special Publications*, 17: 1–277.
- U.S. Fish and Wildlife Service. 1994. Endangered and threatened wildlife and plants; animal candidate review for listing as endangered or threatened species; proposed rule. *Federal Register*, 59(219): 58982–59028.
- VanLandingham, S.L. 1967–1979. *Catalogue of the fossil and recent genera and species of diatoms and their synonyms*, 8 vols. J. Cramer, Lehre & Veduz.
- Williams, A.B., Abele, L.G., Felder, D.L., Hobbs, H.H., Jr., Manning, R.B., McLaughlin, P.A. & Pérez Farfante, I. 1989. Common and scientific names of aquatic invertebrates from the United States and Canada: Decapod crustaceans. *American Fisheries Society Special Publications*, 17: 1–77.
- Wilson, D.E. & Reeder, D.M. (Eds.). 1993. *Mammal species of the world*. Ed. 2. 1206 pp. Smithsonian Institution Press, Washington, D.C.
- Yu, D.S. 1993. A proposed system for stabilizing the names of species, illustrated with reference to the ICHNEUMONIDAE (Hymenoptera). *Bulletin of Zoological Nomenclature*, 50: 7–12.